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The Assessment of Atmospheric Pollution of Heavy Metals with the Help of Ornamental Plants in Isfahan Landscape

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Abstract

Plants are the most common bioindicatorsused in air quality biomonitoring studies because they are immobile and they have more sensitive to the most prevalent air pollutants than humans and animals. To identify the concentrations and sources of heavy metals in ornamental plants of Isfahan landscape, samples of leaves and soil around *Pinuseldarica* and *Nerium oleander* were collected at different distances (1, 4 and 10 km) from the most populated and dense vehicle traffic area of Isfahan and control site with and opposite wind directions (SW and NE).For determination of heavy metal contamination source, plant leaves were washed with distilled water. Finally, concentrations of zinc, lead and cadmium in soil and plant samples were determined by atomic absorption. Heavy metals were found at higher concentrations in the all studied sites in comparison with control. Heavy metal concentrations were increased with reducing distance from contamination center with wind direction. Negligiblecorrelation between plant available Zn and Pb concentrations in soil and metal contents in plant leaves and reduction of these metals by water washing treatment indicated that soil cannot be the source of metal contamination in plants. Both ornamental plants were found to be appropriate indicators for airborne Zn and Pb contamination, especially *Nerium oleander*.

Keywords: Bioindicator, Contamination, Heavy metal, Ornamental plants.

INTRODUCTION

Urbanization is one of the most drastic changes that can be imposed on an environment (Mollov and Valkanova, 2009). Urban ecosystems are comprised of diverse land uses including commercial, industrial, residential, transport, recreational, agricultural and nature areas, resulting in different habitats for plants, animals and human within urban landscape. Urban habitat quality results the integration of different abiotic and biotic components, such as air, soil and water quality, microclimate and the presence of vegetation (Petrova, 2011). The use of plants as passive biomonitors to complete the information on trace elements deposition from fully or semiautomatic gauges, commonly used in current pollution monitoring programs, obtain increasing attention (Petrova, 2011).

Biomonitorsplants are effective collectors which reflect the accumulated effect of environmental pollution and accumulation of toxicants from atomspheric pollution (deposition, binding and solubility of metals on the leaf surface) and soil pollution (concentration and bioavailability of elements in soil) (Petrova, 2011).

The use of higher plants, especially different parts of trees, for air monitoring purposes is becoming more and more widespread. The main advantages are greater availability of the biological material, simplicity of species identification, sampling and treatment, harmless sampling and ubiquity of some genera, which makes it possible to cover large areas. Higher plants also exhibit greater tolerance to environmental changes which is especially important for monitoring areas with elevated anthropogenic influence (Berlizov *et al.*, 2007), therefore higher plants have appeal as indicators in air pollution monitoring in highly polluted areas where other bioindicators as lichens and mosses are often absent (Hoodaji *et al*., 2012). An otherwise in the industrial and urban areas, higher plant can give better quantifications for pollutant concentrations and atmospheric deposition than non-biological samples (Markert, 1993).

The aims of this study were to 1) evaluate monitoring atmospheric heavy metal contaminations by ornamental plants and to 2) identify contamination source in plant.

MATERIALS AND METHODS

Study area settings and sampling

Isfahan is third populated city of Iran, which has arid climate with mean annual rainfall of 140 mm. Leaf and soil (around each plant; 0-20 in depth) samples of Pinuseldarica and Nerium oleander were collected in August 2011 at different distances (1, 4 and 10 km) fromthe most populatedand dense vehicle traffic areaof Isfahan and control site in along two opposite wind directions (SW and NE).One control site for both species was located 50 km away in a village with low traffic in BaghBahadoran region.

Pinuseldarica and Nerium oleander were selected for this study. These two species are the most common ornamental plants; they can survive in a wide temperature range and grow in almost any type of soil. Both species are evergreens but have different responses to metal contaminants due to the different morphological and physic-chemical characteristics of their leaves. Pinuseldarica has acicular leaves (needles) with high cuticle thickness and very high waxy surfaces, while Nerium oleander has lanceolate leaves with high cuticle thickness.

Sample preparation

The leaf samples were divided into two groups. The first group was washed with distilled water to clean dust and deposited substances on leaves for 10 min while the second group was not washed. All samples air dried and then oven dried at 70°C for 48 h to achieve constant mass, milled and sieved through a 35 mesh screen. 1 g milled powder of each sample was weighed and after combusting in electrical furnace, were digested with acid. Soil samples were air dried, ground and passed through a 2 mm sieve.

Chemical analysis

The main soil chemical properties were determined by laboratory analysis. Organic carbon was determined by a modified wet oxidation (Nelson and Sommers, 1982). Soil pH was measured using potentiometric titration of soil extract. Cation exchange capacity was determined by ammonium acetate extraction (Rhoads, 1982). Calcium carbonate was measured by back titration. Soil texture was determined by the Hydrometer method (Gee and Bauder, 1986).

The total and DTPA-extractable concentrations of Zn, Cd and Pb were determined after digestion with 10 ml of 70% HNO_3 and 0.005 M DTPA+ 0.01 M $CaCl_2$+ 0.1 M TEA at pH= 7.3, respectively for soil samples (Soon and Abound, 1993) and with 10 ml 2 N HCl for plant leaves (Chapman and Pratt, 1961).

The metal concentrations in plant and soil samples were determined by atomic absorption spectroscopy (AAS). The results are shown in table1.

RESULTS AND DISCUSSION

Metals concentration in soils

The results indicate that heavy metal concentrations in nearly all cases were higher in studied sites as compared in control site, but only a little fraction of total metal concentrations were available for plants (Table 2). These results can be explained with the consideration of the chemical properties of the soil (Table 1). In the studied soils, high CaCO3 content and pH values, lead to low solubility and availability of metals for uptake by plants.Logan and Chaney (1983) reported that element concentration in plant tissues is not only a function of the total concentration of metals in the soil, but also depends on different factors including element chemical form, pH, organic matter content, texture and CEC of soil (Logan and Chaney, 1983).

There were negligible regression between metal concentrations in plant leaves and DTPA extractable metal concentrations in soils that confirmed above results (Fig.1).

Metals concentration in plant species

Pinuseldarica

The concentrations of Zn, Pb and Cd in leaf samples collected from all studied sites were higher than control (Fig. 2, 3 and 4), but the existence of significant differences were dependent on metal type. The highest and lowest concentrations of all the three metals were observed in B and F sites which were located 4 (SW) and 10 (NE) km away from contamination center. There were significant differences between B and Control site ($p\leq 0.05$). These results are reasonable with regard to distance from contamination center and wind direction (SW and NE with and opposite wind direction, respectively).

Nerium oleander

There were significant differences between the three metal concentrations in leaf samples of studied sites and control site (Fig. 2, 3 and 4), approximately ($p\leq0.05$).The highest and lowest concentrations of all the three metals were observed in A and E sites which were located 10 (SW) and 4 (NE) km away from city center. These results are explainable with wind direction, solely.

Also in other studies, two aforementioned species evaluated good bioindicatorsfor monitoring of airborne heavy metal contaminations (Ataabadi *et al.,* 2010; Rossini Oliva and Mingorance, 2006).

Assessment metal source in plant using water washing treatment

Influence of washing treatment on metal concentrations varied with plant species and element type.The metal concentrations are reduced by water washing in the all cases,but significant reduction was obtained in some samples especially for leaves containing Pb (Tables 3, 4 and 5).

Ataabadi *et al*. (2012) also reported that washing effect varied with various physico-chemical characters of contaminants, plant species, primary level of contaminants and washing time (Ataabadi *et al.*, 2012).

CONCLUSION

The comparison between soil and plant data indicated that metal content in plant leaves cannot be originated from the soil. The variation in heavy metal concentrations in plant leaves between studied sites is due to traffic volume and wind direction. The highest concentrations of Zn, Pb and Cd in Pinuswere found in closest distance from contamination center with wind direction. However traffic emission was found to be main source of metal contamination in the atmosphere, no significant reductions were obtained due to water washing in most cases. Both ornamental plants were found to be good indicators for airborne Zn and Pb contamination, especially Nerium oleander.

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Tables

Table 1. Mean values of chemical soil properties for contaminated and background sites.

	Wind direction	Distance (km)	*Pinus eldarica*				*Nerium oleander*			
			pH	CEC	OM	$CaCO_3$	pH	CEC	OM	$CaCO_3$
				$Cmol^+ kg^{-1}$	%			$Cmol^+ kg^{-1}$	%	
A	SW	10	7.8	10.8	0.53	42	7.9	11.1	0.53	38
B	SW	4	7.6	10	0.48	40	7.9	10.8	0.5	41
D	NE	1	7.9	11	0.64	39	8	10.9	0.5	41
E	NE	4	8	11.5	0.67	45	8.5	12.1	0.63	43
F	NE	10	8.1	12.1	0.7	43	7.6	11	0.49	39
Control	NE	50	7.6	11.5	0.63	26	7.7	11.3	0.6	28

Table 2. Mean total and DTPA-extractble concentration of metals in soils around plant species.

	Pinus eldarica						*Nerium oleander*					
	Zn		Pb		Cd		Zn		Pb		Cd	
	T	D	T	D	T	D	T	D	T	D	T	D
A	78.7a	9.8ab	38ab	2.4ab	3.1a	ND	61.5ab	10.8a	36.5a	2.2a	2.8a	ND
B	81a	10.1a	43.2a	2.7a	3.5a	ND	57.7ab	9.5ab	39a	2.3a	2.8a	ND
D	68.b6	8.7ab	40.9a	2.7a	2.2b	ND	54.3b	8.8bc	31.6ab	2ab	1.9b	ND
E	68.8b	8.6b	33bc	1.9ab	2.3b	ND	51.4b	8.6c	25bc	1.6ab	1.5bc	ND
F	49.1c	5.3c	32bc	1.8ab	1.4c	ND	70a	10.5a	26.5bc	1.4b	3.2a	ND
Control	51.2c	6c	26c	1.6b	1.2c	ND	49.8b	5.8d	20.1c	1.4b	1.1c	ND

T: TotalD: DTPA-extractable

Table 3.The concentrations of Zn in unwashed and washed leaf of plant species ($mg.kg^{-1}$).

Sampling site	*Nerium oleander*			*Pinus eldarica*		
	Washed	Unwashed	T-Test	Washed	Unwashed	T-Test
A	52.1±5	67.1±8.7	ns	29.3±4	44.7±10.4	ns
B	43.1±5.8	48.8±5.4	ns	41.4±2.1	53.6±6.7	ns
D	37.3±2.1	43.2±3.2	ns	29.7±2.2	40.4±2.9	ns
E	26.9±4.5	35.4±1.1	ns	28.9±5.4	41.5±2.4	ns
F	30±1.5	45.2±2	*	29.2±1.3	33.2±1.1	**
Control	24±2.4	28.5±1.9		23.4±0.8	24.9±0.5	

Table 4. The concentrations of Pb in unwashed and washed leaf of plant species (mg.kg^{-1}).

Sampling site	*Nerium oleander*			*Pinuseldarica*		
	Washed	**Unwashed**	**T-Test**	**Washed**	**Unwashed**	**T-Test**
A	10.7±0.6	17.3±0.6	*	5.3±0.8	7.8±0.4	*
B	7.1±1.1	8.9±0.4	ns	6.1±0.8	14.9±1.4	**
D	8.2±0.9	9.7±0.8	***	6.4±1.1	12.7±3	ns
E	5.5±1.4	8.5±0.8	ns	4±0.6	6.5±0.9	ns
F	6.6±0.05	8.6±0.6	ns	5.3±0.4	6.2±0.5	*
Control	0.4±0.008	0.4±0.03		3.4±0.5	4.3±0.3	

Sampling site	*Nerium oleander*			*Pinuseldarica*		
	Washed	**Unwashed**	**T-Test**	**Washed**	**Unwashed**	**T-Test**
A	0.82±0.02	0.97±0.06	ns	0.37±0.04	0.45±0.03	ns
B	0.65±0.08	0.93±0.09	*	0.25±0.03	0.53±0.04	*
D	0.62±0.1	0.84±0.1	*	0.26±0.02	0.59±0.13	ns
E	0.59±0.1	0.88±0.2	ns	0.12±0.009	0.23±0.02	ns
F	0.74±0.2	0.97±0.1	ns	0.17±0.03	0.26±0.03	ns
Control	nd	nd		nd	nd	

Figures

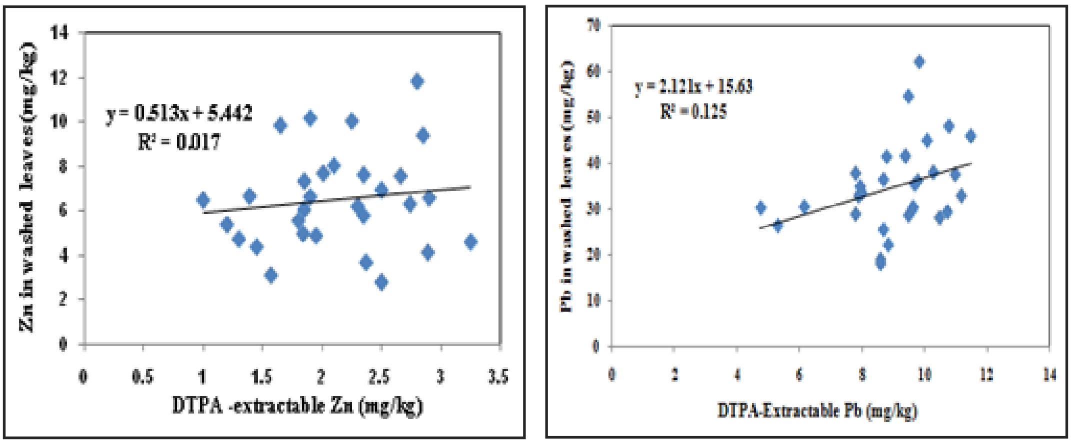

Fig.1.Regression between Zn (Left) and Pb (Right) concentrations in leaves and DTPA-extractable of these metals.

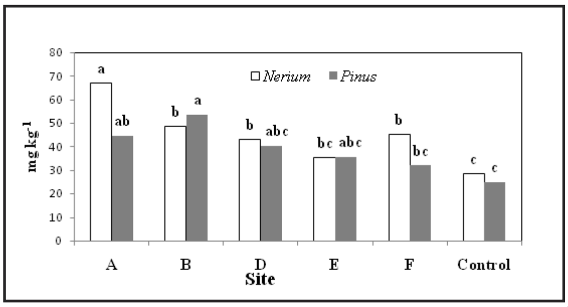

Fig 2. Mean concentration of Zn in leaves of Pinuseldarica and *Nerium oleander* in studied and control sites.

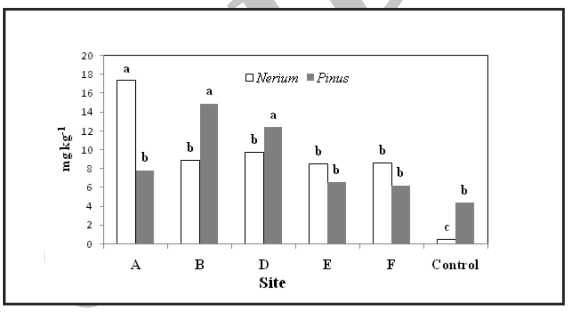

Fig 3. Mean concentration of Pb in leaves of Pinuseldarica and *Nerium oleander* in contaminated and control sites.

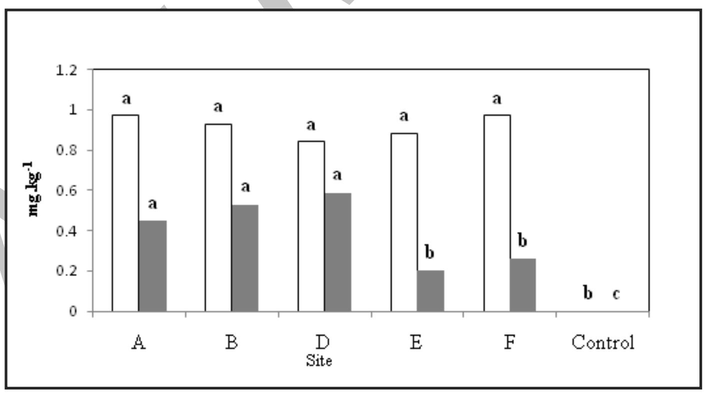

Fig 4. Mean concentration of Cd in leaves of Pinuseldarica and *Nerium oleander* incontaminated and control sites.

Location D: one kilometer from the Centre, the North-East of Isfahan, Modarres Avenue.
Location E: 4 kilometers from the Centre, the North-East of Isfahan, Zeinabiye Avenue.
Location B: 4 kilometers from the Centre, the South-West of Isfahan, Khayam Avenue
Location A: 10 kilometers from the Centre, the South-West of Isfahan, Keshavarz Avenue
Location F: 10 kilometers from the Centre, the North-East of Isfahan, Zeinabiye Avenue.
control: 50 kilometers from the Centre, Bagh-Bahadoran.